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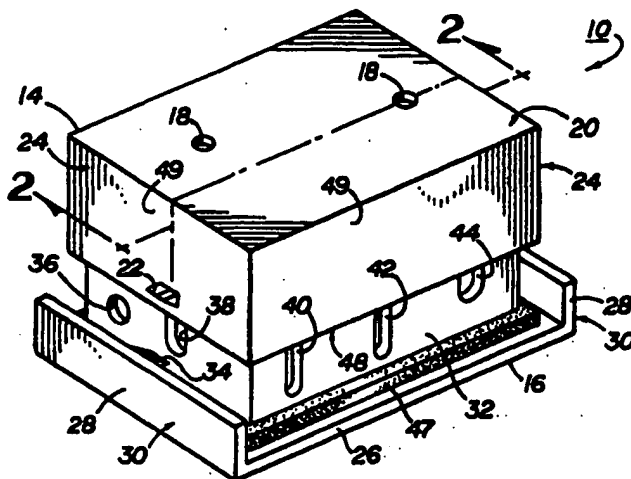
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(71) Applicant: AER ENERGY RESOURCES, INC. (US/US);  
Suite G, 4600 Highlands Parkway, Smyrna, GA 30082 (US).  
(72) Inventor: WITZIGREUTER, John, D.; 4157 Springhill Lane,  
Kennesaw, GA 30144 (US).  
(74) Agents: YOUNG, Jeffrey, E. et al.; Jones & Askew, LLP, 2400  
Monarch Tower, 3424 Peachtree Road, N.E., Atlanta, GA  
30326 (US).

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(54) Title: AIR DELIVERY SYSTEM WITH VOLUME-CHANGEABLE PLENUM FOR METAL-AIR BATTERY

**(57) Abstract**

A ventilation system for a metal-air battery is disclosed. The metal-air battery has one or more air cathodes, one or more air pathways from the air cathode to a reactive gas source, a closure member associated with each of the air pathways to selectively prevent the flow of gas through the air pathways and one or more volume-changeable plenums in fluid communication with the air pathway and the air cathode. When the battery is not in use, the closure member is closed and the door is closed to save the battery lifetime. When the battery is activated, the air pathway is opened and the volume of the plenum is increased to introduce fresh air from the outside to the plenum. A method of producing electricity using a metal-air battery is also disclosed.

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## AIR DELIVERY SYSTEM WITH VOLUME-CHANGEABLE PLENUM FOR METAL-AIR BATTERY

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### BACKGROUND OF THE INVENTION

#### 1. Field of the Invention

The present invention relates generally to batteries, and more particularly relates to an air delivery system with a volume-changeable plenum for a metal-air battery.

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#### 2. Description of the Related Art

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Metal-air battery cells include an air permeable cathode and a metallic anode separated by an aqueous electrolyte. During discharge of a metal-air battery, such as a zinc-air battery, oxygen from the ambient air is converted at the cathode to hydroxide, zinc is oxidized at the anode by the hydroxide, and water and electrons are released to provide electrical energy. Metal-air batteries have a relatively high energy density because the cathode utilizes oxygen from ambient air as a reactant in the electrochemical reaction rather than a heavier material, such as a metal or metallic composition. Metal-air battery cells are often arranged in multiple cell packs within a common housing to provide a sufficient amount of power output. The result is a relatively light-weight battery.

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To operate a metal-air battery cell, it is necessary therefore to provide a supply of oxygen to the air cathodes of the cells. An air

pathway and a plenum are typically used to supply the air cathodes with the oxygen. The air pathway serves as a conduit of the oxygen and the plenum diffuses the oxygen evenly over the air cathodes so as to increase efficiency of the electrodes. The plenum, therefore, has to have a certain  
5 volume to work properly while the battery is operating. The air pathway is generally sealed or closed during non-use by sealing tapes, plugs, mechanical doors, etc., because water vapor and oxygen in the ambient air may cause the cell to flood, dry out, or discharge in certain circumstances, thereby leading to a reduction in cell efficiency and life.  
10 Furthermore, after a period of use, residual water vapor and oxygen in the plenum may cause similar problems, at least immediately after the air pathway is sealed or closed.

Thus, a need exists for an improved metal-air battery cell that overcomes or minimizes the above-referenced disadvantages of prior  
15 art metal-air battery cells.

### SUMMARY OF THE INVENTION

The present invention satisfies the above-described needs by providing a novel metal-air battery. The metal-air battery of the present  
20 invention comprises one or more air cathodes; one or more air pathways from the air cathode to a reactive gas source; a closure member associated with each of the air pathways to selectively prevent the flow of gas through the air pathways; and one or more volume-changeable plenums in fluid communication with the air pathway and the air cathode.

25 The present invention also comprises a method of producing electricity using a metal-air battery comprising one or more air cathodes, an enclosure member at least partially defining a volume-changeable plenum in fluid communication with the air cathode, and at least one closable air pathway in fluid communication with the plenum and ambient  
30 air surrounding the enclosure. The method comprising the steps of opening the air pathway so that the ambient air can flow to said plenum

through the pathway; and increasing the volume of the plenum so that air is drawn through the pathway to the plenum.

In another disclosed embodiment, the present invention comprises an electric device using the metal-air battery mentioned above.

5 Accordingly, it is an object of the present invention to provide an improved metal-air battery.

Another object of the present invention is to provide a metal-air battery that is relatively simple and inexpensive to manufacture.

10 A further object of the present invention is to provide a ventilation system for a metal-air battery that does not require any electric mechanisms to operate it.

Yet another object of the present invention is to provide a metal-air battery that reduces the amount of air in communication with the air cathode when the battery is not in use and increases the amount of  
15 air in communication with the air cathode when the battery is in use.

Another object of the present invention is to provide a metal-air battery with an initial charge of fresh reactive gas for reaction with an air cathode when the battery is activated.

20 These and other objects, features and advantages of the present invention will become apparent after a review of the following detailed description of the disclosed embodiments and the appended drawing and claims.

### **BRIEF DESCRIPTION OF THE DRAWING**

25 Fig. 1 is a perspective view of a disclosed embodiment of the battery of the present invention.

Fig. 2 is a vertical cross-sectional view taken along line 2-2 of the battery shown in Fig. 1.

30 Fig. 3 is an alternate vertical cross-sectional view taken along line 2-2 of the battery shown in Fig. 1 when the battery is in a closed condition.

Fig. 4 is a perspective view of another disclosed embodiment of the battery of the present invention.

Fig. 5 is a vertical cross-sectional view taken along line 5--5 of the battery shown in Fig. 4.

5 Fig. 6 is an alternate vertical cross-sectional view taken along line 5--5 of the battery shown in Fig. 4 when the battery is in a closed condition.

Fig. 7A is a partial vertical cross-sectional view of a pop-open mechanism of the battery shown in Fig. 4 .

10 Fig. 7B is partial detail view of the pop-open mechanism shown in FIG. 7A.

Fig. 7C is an enlarged perspective view of a portion of a pivoting mechanism of the pop-open mechanism shown in Fig. 7.

15 Fig. 8 is a vertical cross-sectional view of another disclosed embodiment of the battery of the present invention.

Fig. 9 is an alternate vertical cross-sectional view of the battery shown in Fig. 8 when the battery is in a closed condition.

Fig. 10A is a partial perspective view of a portion of the closure mechanism of the battery shown in Fig. 8.

20 Fig. 10B is partial detail cross-sectional view of the closure mechanism shown in Fig 10A.

Fig. 10C is partial detail cross-sectional view of the closure mechanism shown in Fig 10A.

25 Fig. 11 is a vertical cross-sectional view of another disclosed embodiment of the battery of the present invention.

Fig. 12 is a vertical cross-sectional view of the battery shown in Fig. 11 showing the battery in a closed condition.

30 Fig. 13 is a schematic view of a disclosed embodiment of an electric device employing a battery of the present invention showing the electric device in an operational condition.

FIG. 14 is a schematic view of the electric device shown in Fig. 13 showing the electric device in non-operational condition.

### DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now in more detail to the drawing, in which like numerals refer to like elements throughout the several views, Figs. 1, 2, and 3 show a disclosed embodiment of the metal-air battery 10 of the present invention. The metal-air battery 10 includes a plurality of metal-air cells 12, such as zinc-air cells, enclosed within an upper cell case 14 and a lower cell case 16. The present invention is useful with both primary and secondary metal-air cells. Primary and secondary metal-air cells are known in the art and suitable components for primary metal-air cells are described in U.S. Pat. No. 5,721,065 (the disclosure of which is incorporated herein by reference). Secondary cells also can be used in the present invention, such as that described in U.S. Patent 5,569,551 (the disclosure of which is incorporated herein by reference). Although the use of the present invention is disclosed as useful with a zinc-air battery, it should be understood that the present invention is applicable to other types of metal-air battery cells.

The upper case 14, which is a rectangular box shape with the bottom face open, contains the cells 12 inside and optionally has two openings 18 on the top face 20 for injecting electrolyte into the cells and venting or exhausting evolved gas. The upper case 14 also has two projections 22 on its opposite side faces 24. The lower case 16 has a tray 26 with two leg portions 28 projecting upwardly at the side edges 30 and a four-sided wall 32 sitting on the tray 26 and extending upwardly. Each leg portion 28 has a projection 34 extending inwardly. The wall 32 has several openings, such as a circular opening 36, and slits or vents 38, 40, 42, 44. The vents 38, 40, 42, 44 have a variety of widths and each has a round end at its bottom portion. The vents 38, 40, 42, 44 may be open at the top edge 46.

Within the upper case 14, a plurality of metal-air cells 12 are secured to the underside of the top face 20 of the upper case 14. Two identical upper pillars 52 of a telescopic mechanism are also secured to the

underside of the top face 20 of the upper case 14. At the other end of each pillar 52 is formed a salient portion 54. A lower hollow pillar 56 of the telescopic mechanism surrounds each the upper pillar 52 and has a smaller opening at the top end 58. The salient portion 54 of each upper pillar 52 is smaller than the hollow tube of each lower pillar 56 but larger than the smaller opening 58 at the top end so as to prevent the upper pillar 52 from being removed completely from the lower pillar 56. The upper and lower pillars 52, 56 are surrounded by a coil compression spring 60. Opposite ends of the springs 60 contact the underside of the top face 20 of the upper case 14 and the top side 62 of the bottom face 63 of the lower case 16. The springs 60 apply a force to the upper case 14 and lower case 16 tending to bias the two case halves apart.

The upper case 14 and lower case 16 define a volume-changeable plenum 64. The plenum 64 is disposed under and around the cells 12 so as to diffuse a reactive gas from the plenum 64 to the cells 12.

The outside dimension of the four-sided wall 32 of the lower case 16 is slightly smaller than the inside dimension of the box-shaped upper case 14 so that the upper and lower cases fit together telescopically, and, thus, permit the wall 32 to slide on the inside of the box-shaped upper case. This telescopic arrangement permits the upper case 14 to move upwardly and downwardly with respect to the lower case 16. When the upper case 14 is in the position shown in Fig. 2, the vents 36, 38, 40, 42, 44 permit the ambient air surrounding the battery 10 to enter the plenum 64 and also permit air inside the plenum 64 to escape to the outside.

When the battery 10 is stored, inactive or otherwise not operative, the upper and lower cases 14, 16 are pressed together so that the battery case may be in a collapsed or closed position, as shown in Fig.3, and the projections 22 of the upper case 14 engage the projections 34 of the portion 28 of the lower case 16. The projections 22 have a horizontally flat portion 65 at their upper portion and a wedge shape 66 at their lower portion. The projections 34, on the other hand, have a



horizontally flat portion 67 at their lower part and a wedge shape 68 at their upper part. Thus, the two wedge-shaped portions 66, 68 slide on their surfaces to push outwardly when the upper and lower cases 14, 16 are pressed together. When the battery case is in a collapsed position, the  
5 projection 34 of the lower case 16 moves back or springs back inwardly to engage with the projection 22 on its flat portion 67 like a ratchet so that the battery case may be retained in the collapsed position. In the collapsed or closed position (Fig. 3), the box-shaped upper case 14 covers the openings 36, 38, 40, 42, 44 thereby closing them, and, thus, preventing  
10 the ambient air surrounding the battery 10 from entering the plenum 64 and also preventing air inside the plenum 64 from escaping to the outside.

When the battery is ready to use, the projections 34 are moved outwardly against the elastic force of the leg portions 28. Thus, the engaged projections 22, 34 are released and the upper case 14 is  
15 popped open by the elastic force of the coil spring 60. At the same time, the volume-changeable plenum 64 is expanded and a negative gauge pressure is produced inside of the case, which causes ambient air surrounding the battery 10 to be drawn through the vents 36, 38, 40, 42, 44 during the opening movement. The fresh air, including a reactive gas;  
20 *i.e.*, oxygen, is therefore, introduced into the expanded plenum 64 and supplies the air cathodes (not shown) with oxygen for immediate use. The inflow of air through the vents 36, 38, 40, 42, 44 during the opening movement also causes turbulence inside of the case which aids in the diffusion of oxygen evenly over the air cathodes (not shown).

25 When the battery is not in use, the upper and lower cases 14, 16 are pressed together against the elastic force of the coil spring 60 to the collapsed position (Fig.3). As the upper and lower cases 14, 16 move toward each other, the plenum 64 becomes smaller which thereby cause air inside the plenum 64 to be exhausted through the vents 36, 38, 40, 42, 44. When completely closed, the upper case 14 covers the vents 36, 38, 40,  
30 42, 44, as described above, and prevents air from both entering and exiting the plenum 64.

The four-sided wall 32 of the lower case 16 can have any number or any shape of vents 36, 38, 40, 42, 44. It is within the skill of the art to design the vents to provide sufficient ventilation for optimum battery performance during steady state, as well as transition state, use.

5 The distance that the upper and lower cases 14, 16 move in the opening and closing movement directly affects a volume change ratio of the plenum 64 and can also be adjusted for optimum battery performance. If that distance is relatively short, the volume change ratio is relatively small and produces relatively small pressure differences; if that distance is

10 relatively long, the volume change ratio is relatively large and produces relatively large pressure differences. Useful closing distances are typically from 60,000 micro inches to one-quarter of an inch if the wall 32 has many vents.

Since a relatively small positive pressure remains in the plenum 64 after all the openings 36, 38, 40, 42, 44 are closed, it is desirable to provide the plenum 64 with a vent hole with a check valve as described further hereinbelow.

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The top view of the upper case 14 is rectangular in this embodiment, but it will be understood that the upper case can have any desired shape, such as polygonal or circular, as described later. Any number or any shape of the engaging projections 22, 34 may also be used in accordance with the present invention as long as the engaging mechanism retains the upper and lower cases 14, 16 in the collapsed or closed position and can be relatively easily released so that the upper and lower cases can assume the open position. The upper and lower cases 14, 16 can be made from any suitable material, however, plastic is preferred because it is gas-impermeable, relatively easy and inexpensive to form into a desired shape, and because it can be self-lubricating so as to facilitate the sliding mechanism. Metal or other materials may also be used.

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The coil spring 60 is of a suitable size so as to provide sufficient force for opening the upper and lower cases 12, 14. The elastic force may be adjusted to achieve the optimal pop-opening rate and to

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give suitable resistance for closing by hand. However, the spring 60 can also be designed so as to provide more space for the cells 12.

Another disclosed embodiment of the present invention is shown in Figs. 4, 5, 6, 7A, 7B and 7C. The metal-air battery 10' includes a  
5 cylindrical cell 70 enclosed within a circular upper cell case 72 and a circular lower cell case 74. The figures show a flat or a button type of battery. However, it should be understood that the battery could be made taller, for example, size "D" or "AA".

The upper case 72, which is shaped like an upside down cup,  
10 has an optional opening 76 on the top face 78 for injecting electrolyte into the cell 70 and ventilating evolved gas. The lower case 74 has a base 80 and a circular wall 82 extending upwardly therefrom. The wall 82 has several slit openings or vents 84 each having the same size and shape for symmetry. Each opening 84 is round at the bottom ending and may be  
15 open at the top edge 88. The base 80 has an opening 90 and a reducing valve 92 to leak pressured air from a volume-changeable plenum 94 during battery collapse or closing.

Inside the upper and lower cases 72, 74 (collectively "the battery case"), a cell 70 is secured to the underside of the top face 78 of the  
20 upper case 72. An upper pillar 96 of a telescopic mechanism is also secured to the underside at the top face 78 of the upper case 72. At the distal end of the pillar 96 a snap ring 98 is secured to retain an opening mechanism described later. A lower pillar 100 of the telescopic mechanism is secured to the center of the top face 102 of the base 80. The  
25 hollow pillar 100 surrounds a lower portion of the upper pillar 96 and has a smaller opening 104 at the top end of the lower pillar 100. A coil spring 106 surrounds the upper pillar 96 and is disposed between the topside of the top face 78 of the upper case 72 and a circular plate 108 at the top end of the lower pillar 100 so as to push the upper case 72 and the lower case  
30 74 apart. Therefore, the opening, which is defined by the circular plate 108 at the top end of the lower pillar 100 is smaller than the diameter of the coil spring 106.

In Figs. 7A, 7B, and 7C, the opening mechanism is illustrated. The upper pillar 96 holds a rotatable cylindrical member 110 between the snap ring 98 and another snap ring 112 secured to the upper pillar 96. The cylindrical member 110 has a clearance hole 114 for the upper pillar 96, rectangular teeth 116 on the top face 118, and saw teeth 120 on the bottom face 122. Inside the hollow pillar 100, a stationary cylinder 124 with rectangular teeth 126 on the bottom face 128 is secured to the circular plate 108, and a stationary cylinder 130 with saw teeth 132 on the top face 134 is secured to the base plate 80. Each rectangular tooth 136 of the stationary cylinder 124 has a plateau 138 and a triangle portion 140 on the right corner with neighboring concavities 142, as shown in Fig. 7B. On the top face 118 of the rotatable cylindrical member 110, each rectangle tooth 143 has a plateau 144 and a chamfered right corner 146 with neighboring concavities 148. Each cavity 148 has a triangular cavity 150 on the right. The triangular portion 140 fits the chamfered corner 146 and the cavity 150. On the bottom face 122 of the rotatable cylindrical member 110, each saw tooth 152 has a peak 154 and a wedge-like slope 156 at the right hand side. On the top face 134 of the stationary cylinder 130, each saw tooth 158 has a peak 160 and a wedge-like slope 162 on the left-hand side. Thus, both saw teeth 120, 132 engage with each other. A typical bottom face 122 of the rotatable cylindrical member 110 is shown in Fig. 7C. A typical top face 134 of the stationary cylindrical member 130 is similar to the bottom face 122 except with a large hole at the center.

When the battery is in a collapsed or closed position, the plateau 138 of the tooth 136 of the stationary cylinder 124 coincides with the plateau 144 of the tooth 116 of the rotatable cylinder 110 such that the rotatable cylindrical member 110 is kept in a lower position in the hollow pillar 100 (Fig. 6). That means the upper case 72 is in the collapsed position. When the upper case 72 and the lower case 74 are pressed together to move the upper shaft 96 downwardly, the peak 154 of each saw tooth of the rotatable cylinder 110 hits on the wedge-like slope 162 of the stationary cylinder 130 and the peak 160 of each saw tooth 158 of the

stationary cylinder 130 hits on the wedge-like slope 156 of the rotatable cylinder 110. Because of the slope, the peak 154 moves left in Fig. 7B while the upper case 72 and the lower case 74 are pressed together; *i.e.*, while the rotatable cylinder 110 and the stationary cylinder 130 are pressed together. Here, the term "moves left" means "rotates clockwise" if the rotatable cylinder 110 is viewed from the top. After the peak 154 of the saw tooth 152 reaches a notch 164 of the counter saw tooth of the stationary cylinder 130, the clockwise movement of the rotatable cylinder 110 is blocked by each vertical wall of the saw teeth of both the rotatable cylinder 110 and the stationary cylinder 130.

When the pressure is released, the coil spring 106 pushes the upper case 72 back to the open position in a manner described hereafter. The rotatable cylinder 110 is lifted to bring the rectangle tooth 136 into contact with the corresponding rectangle tooth 116 when the spring 106 pushes up on the upper case 72 and the rotatable cylinder 110. However, since the rotatable cylinder 110 has been moved left about half of the breadth of the rectangle tooth 136 as described before, the left corner of the tooth 136 hits on the chamfered corner 146 and each tooth 143 of the rotatable cylinder 110 rotates to fall into each corresponding concavity 142. Thus, the rotatable cylinder 110 is retained in the open position (Fig. 5).

When the upper case 72 and the lower case 74 are pressed together, the rotatable cylinder 110 is pushed downward to bring the saw teeth 120 at the bottom face 122 into contact with those at the top face 134 of the stationary cylinder 130. The peak 154 of each saw tooth 152 of the rotatable cylinder 110, thereby, hits on the wedge-like slope 162 of the stationary cylinder 130 to move clockwise as described above. Then, the pressure is released so that the rotatable cylinder 110 is pushed upwardly by the spring 106 to bring the rectangular teeth 116 into contact with the rectangular teeth 136 again. The triangular portion 140 slides on the chamfered corner 146 to move the rotatable cylinder 110 slightly clockwise such that the plateau portion 144 of the rotatable cylinder 110

sits on the plateau portion 138 of the stationary cylinder 124. Thus, the battery case is kept in the closed position again and the rotatable cylinder 110 is kept in the lower position in the hollow cylinder 100.

5 When the battery 10' is stored or is otherwise inactive, the upper and lower cases 72, 74 are pressed together so that the battery case is in the collapsed or closed position (Fig. 6). Thus, the openings 84 are closed by the side wall of the upper case 72 and the volume-changeable plenum 94 is also collapsed (Fig. 6).

10 When the battery is ready to be used, the battery is opened by the elastic force of the coil spring 106 with the opening mechanism described above (Fig. 5). At the same time, the volume-changeable plenum 94 is expanded and a negative gauge pressure is produced inside of the case, which causes air outside of the openings 84 to be drawn into the plenum 94 during the pop-open movement. The fresh air, including a  
15 reactive gas; *i.e.*, oxygen, is introduced into the expanded plenum 94 and supplies the air cathode (not shown) with oxygen for immediate use. The inflow of air through the openings 84 also causes turbulence within the plenum 94 which causes the oxygen to diffuse evenly over the air cathode (not shown).

20 When the battery is not in use, the upper and lower cases 72, 74 are pressed together against the elastic force of the coil spring 106 to the collapsed position (Fig.6). As the upper and lower cases 72, 74 move toward each other, the plenum 94 becomes smaller which causes air inside the plenum 94 to be exhausted through the openings 84 just before they  
25 are closed completely by the upper case 72 and through the opening 90 after the openings 84 are closed. The reducing valve 92 is composed of a plate like a petal and a hinge (not shown) securing the valve 92 to the bottom face of the base 80. The valve 92 closes the opening 90 with a weak closing force provided by a spring at the hinge (not shown) unless  
30 there is a positive gauge pressure in the plenum 94.

The cylindrical wall 82 of the lower case 74 may have any number or any shape of vent openings 84. It is within the skill of the art to

design the vents to provide sufficient ventilation for optimum battery performance during steady state, as well as transition state, use. The distance that the upper and lower cases 72, 74 move in the opening and closing movement directly affects the volume change ratio of the plenum 94 and can also be adjusted for optimum battery performance as previously described.

The top view of upper case 72 is circular in this embodiment, but it can be any desired shape, such as polygonal, as mentioned above. Any suitable mechanism for opening and closing the upper and lower cases 72, 74 can be employed in accordance with the present invention.

Another embodiment of the present invention is illustrated in Figs. 8, 9, 10A, 10B and 10C. Although most of the parts of this battery 10" are commonly used in the previous embodiment (Figs. 4-7C), the battery has a mechanical door located beneath an air cathode (not shown) of a metal-air cell 70, a plurality of pillars 170 for a door opening and closing mechanism, and a plurality of openings 172 for air communication. The mechanical door comprises two circular disks 174, 176 with a plurality of holes 178, 180, 182, 184 formed therein and a spring (not shown) to push it back to an open position. Each pillar 170 for the door opening and closing mechanism has a wedge-like portion 186 at the top end (Figs. 10A, 10B and 10C). The base 80 has a plurality of openings 172 so that the air can enter the plenum 94 from the outside and can also exit the plenum 94 through the openings 172

The circular disks 174, 176 are disposed just beneath the cell 70. Therefore, the volume-changeable plenum 94 is separated from the air cathode (not shown) by the circular disks 174, 176. Air freely enters and exits the plenum 94 through the openings 172. The openings 172 can be diffusion tubes that restrict the flow of excess air and water vapor or larger tubes for continuous operation. The circular disks 174, 176 may have many openings 182, 184 formed therein because only a small space is available for diffusion between the openings and the cathode. However,

the openings 172 may prevent solid particles and other harmful materials from entering the battery cells 70.

The opening and closing of the mechanical door coincides with a volume change of the plenum 94 as described hereafter. The mechanical door is open; *i.e.*, the openings 182, 184 on both disks 174, 176 align with each other, by the action of a spring (not shown) when the battery case is in an open position (Fig. 10B). However, the mechanical door is closed; *i.e.*, the openings 182, 184 do not align with each other (Fig. 10C), because the lower disk 176 is moved by the pillars 170. Each pillar 170 extends through a corresponding opening 180 for alignment and the slant cut end 186 of each pillar 170 moves the lower disk 176 when the case is collapsed or closed. The use of the mechanical door to isolate the metal-air cell from ambient air provides a longer shelf life than for conventional metal-air battery cells.

Another embodiment of the present invention is illustrated in Figs. 11 and 12. The battery 10''' includes a metal-air cell 190 secured within an upper case 192, which may be shaped like an upside down cup. Disposed under the cell 190 is a volume-changeable plenum 194. The plenum 194 is also defined by a lower case 196 including a bellows portion 198 with openings 200 formed therein. The bellows can be made of rubber, plastics, and other suitable flexible materials, so that the openings 200 can be closed by the adjacent rib 202 of the bellows facing the openings 200 when the battery case is in a collapsed or closed position (Fig. 12).

When the battery is stored or is otherwise inactive, the upper and lower cases 192, 196 are pressed together thereby compressing the bellows so that the battery case is in a collapsed position (Fig. 12) and so that the openings 200 are closed as described above.

When the battery 10''' is ready for use, the battery case is popped-open by the elastic force of bellows or is stretched by hand (Fig. 11). At the same time, the volume-changeable plenum 194 is expanded and the openings 200 accordingly become open. A negative gauge



pressure is produced in the plenum 194 and causes ambient air surrounding the battery 10''' to flow into the plenum through the openings or vents 200. Fresh air, including a reactive gas; *i.e.*, oxygen, therefore, is introduced into the expanded plenum 194 to supply the air  
5 cathode with oxygen for immediate use.

When the battery 10''' is not in use, the upper and lower cases 192, 196 are pressed together against the elastic force of the bellows to the collapsed position (Fig.12). At the same time, the plenum 194 becomes smaller so as to exhaust air inside the plenum through the  
10 openings 200. The lower case 196 optionally includes a reducing valve, of the type described above, such that a positive air pressure in the plenum 194 is avoided.

Further the opening and closing motion facilitates air movement and fresh air introduction into the plenum 186 and the air  
15 cathode (not shown). Thus, the volume-changeable plenum works as a fresh air pump or an air manager of the metal-air battery which is disclosed, for example, in U.S. Pat. No. 5,356,729.

Another embodiment of the present invention is illustrated in Figs. 13 and 14. The battery of the present invention is illustrated as  
20 being installed in a camcorder 210, which has a foldable handle 212 to hold the body of the camcorder while shooting. Any type of batteries described theretofore can be used in the camcorder 210. When the handle 212 is unfolded (Fig. 13), the battery case 214 expands thereby expanding the volume-changeable plenum so that fresh air enters the plenum. When  
25 the handle 212 is folded (Fig. 14); *i.e.*, the camcorder is not in use, the expanded battery case is pushed back by the handle 212 to the closed position and volume-changeable plenum is compressed expelling air therefrom and the openings are closed to save battery life.

It should be understood, of course, that the foregoing relates  
30 only to certain disclosed embodiments of the present invention and that numerous modifications or alterations may be made therein without

departing from the spirit and scope of the invention as set forth in the appended claims.

## CLAIMS

What is claimed is:

- 5           1.   A metal-air battery comprising:  
            one or more air cathodes;  
            one or more air pathways from said air cathode to a reactive  
gas source;  
            a closure member associated with each of said air pathways  
10       to selectively prevent the flow of gas through said air pathways; and  
            one or more volume-changeable plenums in fluid  
communication with said air pathway and said air cathode.
- 15           2.   The metal-air battery of Claim 1, wherein said air cathodes  
are enclosed in an enclosure member that isolates said air cathodes from  
said reactive gas source.
- 20           3.   The metal-air battery of Claim 2, wherein said air pathways  
are formed in said enclosure member.
- 25           4.   The metal-air battery of Claim 3, wherein said enclosure  
member at least partially defines said volume-changeable plenum.
- 30           5.   The metal-air battery of Claim 4, wherein said enclosure  
member comprises at least a first member and said closure member  
cooperates with said first member such that when said first member and  
closure member are in a first position, said plenum has a volume and  
when said first member and closure member are in a second position, said  
plenum has a relatively larger volume.
6.   The metal-air battery of Claim 5, wherein said first member  
and said closure member interfit with each other telescopically.

7. The metal-air battery of Claim 6, wherein said air pathways are formed in said first member such that when said first member and closure member are in said first position, said closure member covers said air pathways in said first member and prevents gas from flowing through said air pathways, and when said first member and closure member are in said second position, said closure member does not cover said air pathways thereby permitting gas to flow through said air pathways.

8. The metal-air battery of Claim 1, wherein movement of said closure member produces a change in the volume of said volume-changeable plenum.

9. The metal-air battery of Claim 1, wherein said closure member is disposed between said volume-changeable plenums and said reactive gas source.

10. The metal-air battery of Claim 1, wherein said closure member is disposed between said volume-changeable plenums and said air cathodes.

11. The metal-air battery of Claim 1, wherein said air pathway has an opening disposed around a periphery of said battery.

12. An electric device using the metal-air battery of Claim 1.

13. The electric device of Claim 12 further comprising an electric switch for turning the device on and off wherein actuation of said switch also actuates said closure member.

14. A metal-air battery comprising:

one or more air cathodes, said cathodes being enclosed in an enclosure member, said enclosure member also at least partially defining a volume-changeable plenum in fluid communication with said air cathode, said enclosure member comprising a first member and a second member;

said first and second members having a first position wherein said plenum has a volume and said first and second members having a second position wherein said plenum has a relatively larger volume;

at least one vent formed in said first member such that said plenum is in fluid communication with ambient air surrounding said enclosure member when said first and second members are in said second position and said vent being closed when said first and second members are in said first position.

15. A method of producing electricity using a metal-air battery comprising one or more air cathodes, said cathodes being enclosed in an enclosure member, said enclosure member also at least partially defining a volume-changeable plenum in fluid communication with said air cathode, and at least one closable air pathway in fluid communication with said plenum and a reactive gas source, said method comprising the steps of:

opening said air pathway so that reactive gas can flow to said plenum through said pathway; and

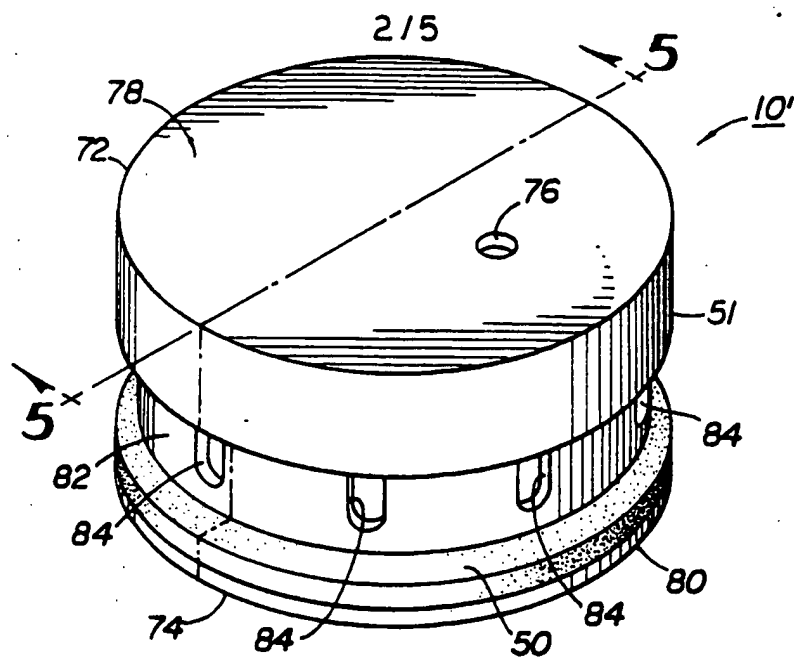
increasing the volume of said plenum so that reactive gas is drawn through said pathway to said plenum.

16. The method of Claim 15, wherein said volume of said plenum is increased by changing the dimensions of the portion of the enclosure member at least partially defining the plenum.

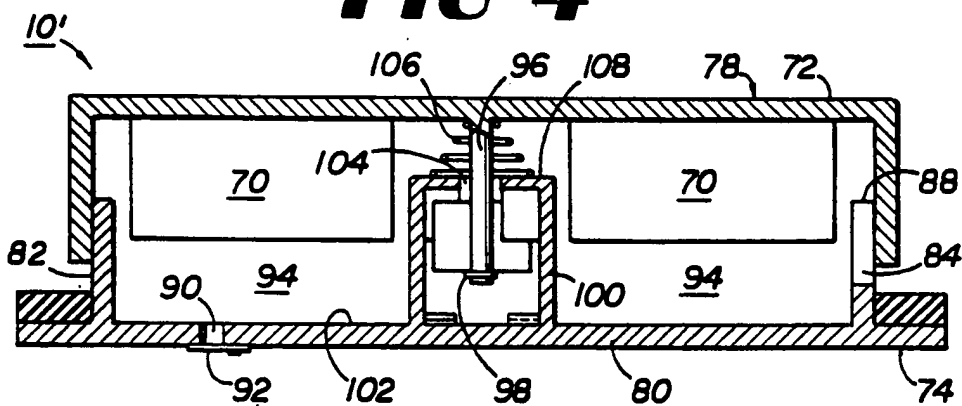
17. The method of Claim 15, wherein said reactive gas source is ambient air.

5 18. The method of Claim 17, wherein said steps of opening said air pathway and increasing the volume of said plenum are done simultaneously.

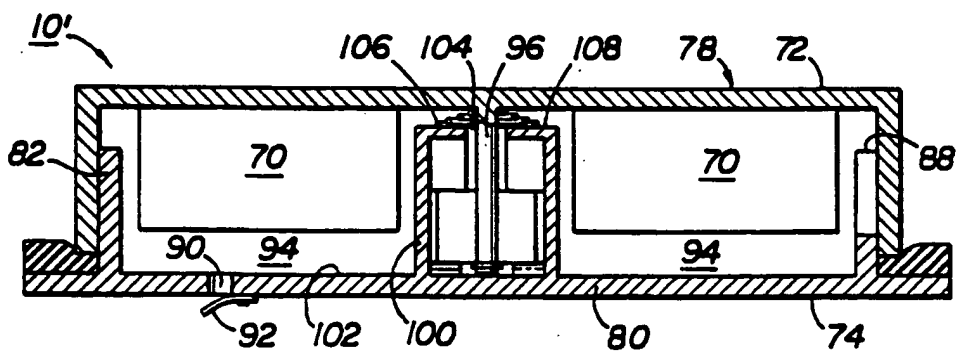




**FIG 4**

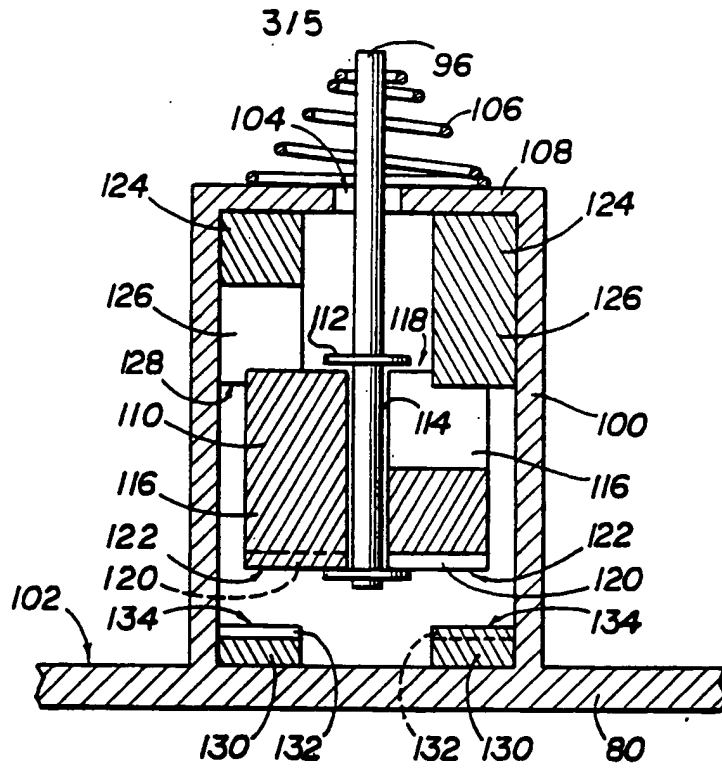


**FIG 5**

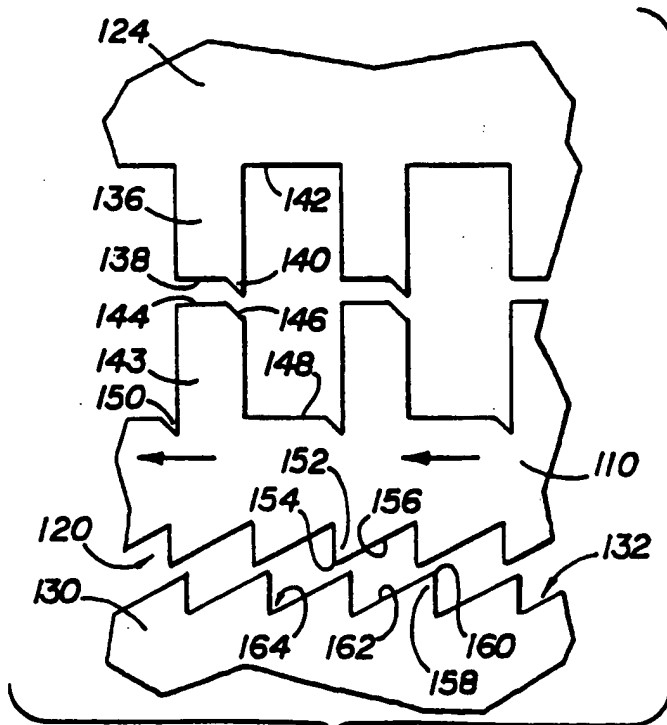


**FIG 6**

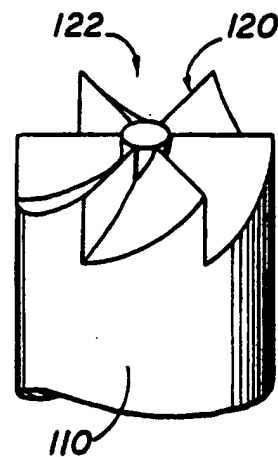




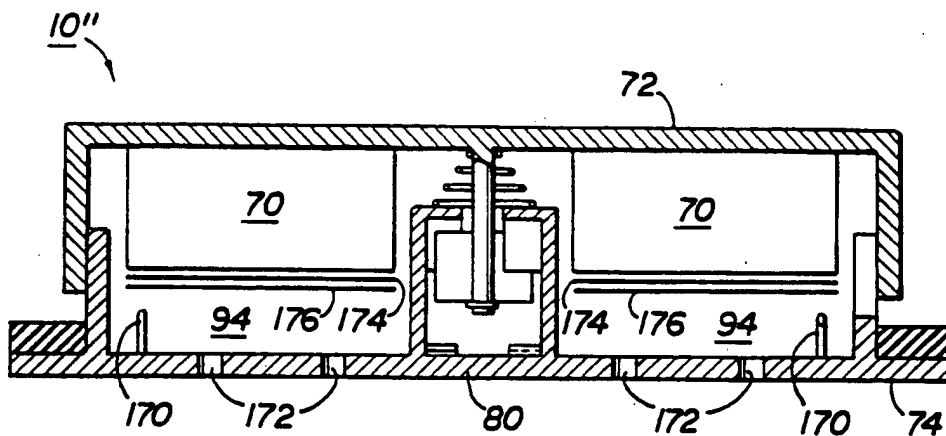
**FIG 7A**



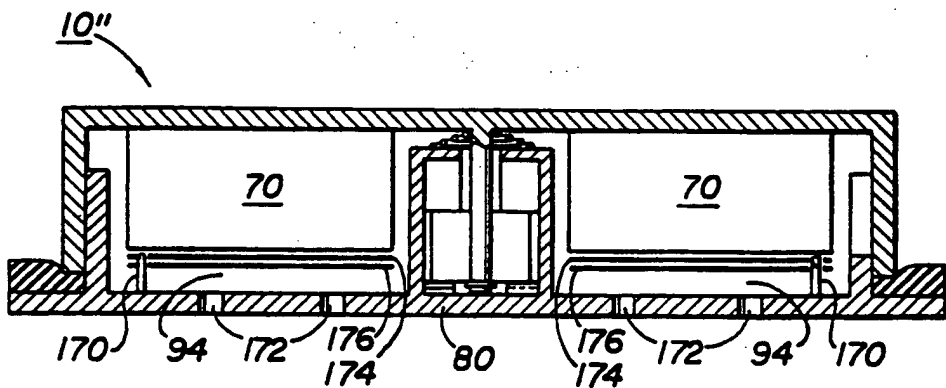
**FIG 7B**



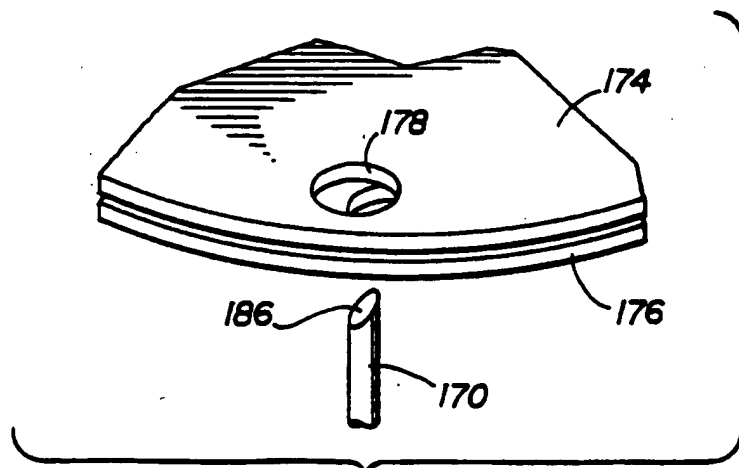
**FIG 7C**



**FIG 8**

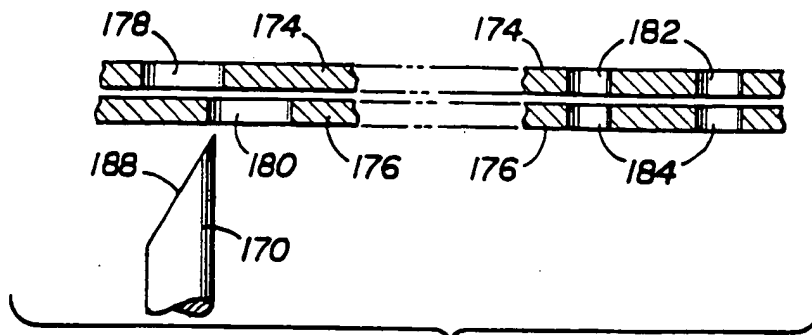


**FIG 9**

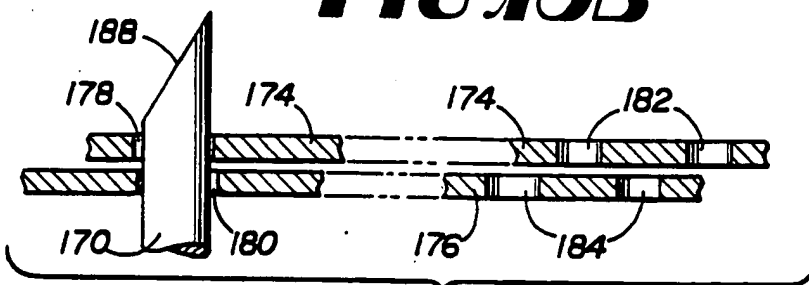


**FIG 10A**

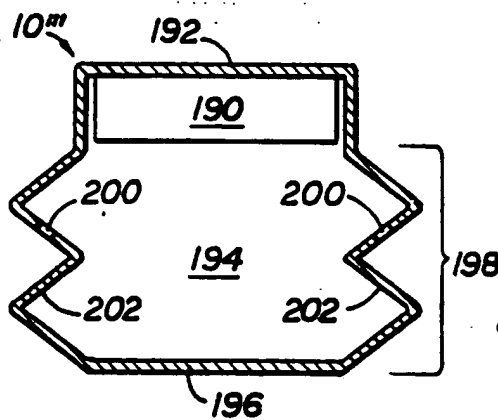
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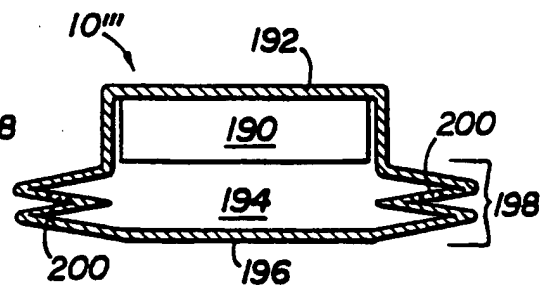
**FIG 10B**



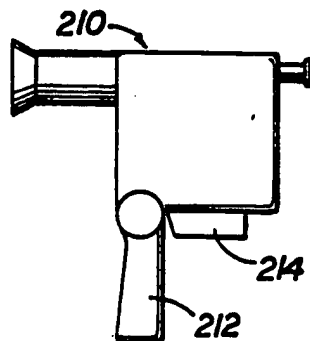
**FIG 10C**



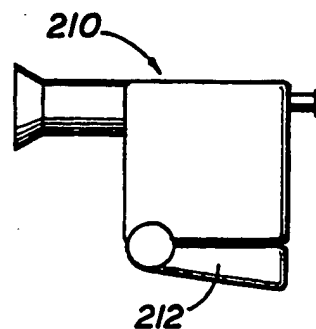
**FIG 11**



**FIG 12**



**FIG 13**



**FIG 14**

# INTERNATIONAL SEARCH REPORT

Int. Application No  
**PCT/US 99/29913**

**A. CLASSIFICATION OF SUBJECT MATTER**  
**IPC 7 H01M12/06**

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)  
**IPC 7 H01M**

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DATABASE WPI Section Ch, Week 199843 Derwent Publications Ltd., London, GB; Class L03, AN 1998-504787 XP002137452 & RU 2 106 722 C (LI S A), 10 March 1998 (1998-03-10) abstract	1          14,15
A		
X	PATENT ABSTRACTS OF JAPAN vol. 018, no. 586 (E-1627), 9 November 1994 (1994-11-09) & JP 06 223882 A (AISIN SEIKI CO LTD), 12 August 1994 (1994-08-12) abstract	1          14,15
A		
	— -/-	

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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Date of the actual completion of the international search

**11 May 2000**

Date of mailing of the international search report

**25/05/2000**

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2  
NL - 2280 HV Rijswijk  
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,  
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**Andrews, M**

# INTERNATIONAL SEARCH REPORT

Interv. Application No  
PCT/US 99/29913

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passage	Relevant to claim No.
A	WO 97 44848 A (AER ENERGY RESOURCES INC) 27 November 1997 (1997-11-27) claim 1; figure 1	1,14,15

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Information on patent family members

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JP 06223882 A	12-08-1994	NONE	
WO 9744848 A	27-11-1997	US 5721064 A CA 2255700 A EP 0907981 A JP 11514137 T	24-02-1998 27-11-1997 14-04-1999 30-11-1999